Overview of Induced Earthquakes in Central and Eastern North America

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After 2010, the rate of M≥3.0 earthquakes dramatically increased in the central and eastern United States (CEUS) compared to the rate observed between 1967 and 2000 (Ellsworth, 2012). Nine of the ten M≥4.5 earthquakes in the CEUS since January 2010 occurred within areas of active oil or gas production, and 8 of these events occurred in close proximity (<10 km) to one or more fluid-waste disposal wells. Such a high degree of spatial association suggests a causal relationship between some of these earthquakes and fluid injection at the waste-disposal wells. The largest recent earthquake linked to fluid injection is the 2011 Mw5.7 Prague, Oklahoma, earthquake that destroyed 14 homes and injured 2 people (Keranen et al., 2013).

Induced earthquakes that primarily release stresses created by the fluid injection have small magnitudes (OGS, 2014). However, induced earthquakes that are triggered by the fluid injection but primarily release tectonic stresses may have energy available for larger, potentially damaging earthquakes. Well-documented cases of induced earthquakes clearly triggered by fluid-waste injection include Rocky Mountain Arsenal (RMA), Colorado (Healy et al., 1968); ParadoxValley, Colorado, (Ake et al., 2005); Guy-Greenbrier, Arkansas, (Horton, 2012); and Youngstown, Ohio (Kim, 2013). In these cases, induced earthquakes were found to occur at distances up to 10+km from the wells, primarily at shallow depths in the Precambrian basement below the injection interval. In each case the injection was at relatively high pressure, and the seismicity started soon after injection began. Seismicity continued for the duration of injection with the largest earthquakes significantly after seismicity began. Injection pressures were low at wells near the Prague, Oklahoma, earthquake, and the first observed earthquakes occurred 17 years after injection began. For all triggered earthquakes, the source is consistent with expectations for the regional stress field.

The size of induced earthquakes can apparently be managed and problems ameliorated when recognized and acted upon. At Guy-Greenbrier, Arkansas and Youngstown, Ohio, the seismicity dramatically decreased and soon ceased after injection was stopped. At Paradox Valley, injection volume and pressure have been strategically adjusted to limit earthquake size and frequency over 20 years. Local seismic monitoring and more detailed injection histories at the wells provide critical information required for management. Future earthquakes in the CEUS (including large and damaging earthquakes) have □60% probability of occurring within 14 km of past earthquakes (Kafka, 2007). Continued fluid injection in close proximity to recent earthquakes raises the expectation of triggering future events.

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